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FOREST INSECT INVESTIGATIONS

DOUGLAS FIR BEETLE INVESTIGATIONS
1931

by
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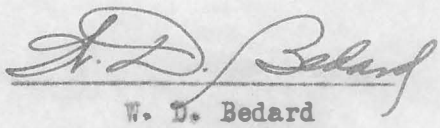
Respectfully submitted,



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INTRODUCTION

During the past few years depredations by the Douglas fir beetle (Dendroctonus pseudotsugae Hopk.) have become increasingly severe throughout the Douglas fir stands of the northwestern United States. In fact, the damage became so serious that control projects were instituted against this insect on the Glacier National Park in 1930 and on the Shoshone National Forest in 1931. The seriousness of this situation and the need for a better knowledge of the biology and habits of the beetle, upon which improved methods of control might be developed, were realized, and therefore a study of the Douglas fir beetle was instituted early in 1930 on the Kaniksu National Forest, near Metaline Falls, Wn. The investigation was continued in 1931 and comprised the main study for the entire field season. The following is a report of all the work accomplished to date.

THE DOUGLAS FIR BEETLE

The Douglas fir beetle was described by Dr. A. D. Hopkins* in 1909. It attacks Douglas fir, western larch, and has been recorded from bigcone spruce, although Douglas fir is the main host. The fresh attacks are indicated by red boring dust at the gallery entrances and lodged in the bark crevices and loose bark along the trunk of the tree. The foliage

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* Hopkins, A. D. 1909 - The Genus Dendroctonus. U. S. D. A. Bulletin 83.

of the infested trees usually fades and turns red by late September of the season of attack, although this is not a sound criterion for the recognition of infested trees, because the leaves of many persist in a faded or green state until the following spring.

Seasonal History and Habits

The main attack of this beetle begins about the middle of May and continues until the end of the month, with a few attacks occurring in early June. Upon arrival at the new host, the female beetle excavates the horizontal entrance tunnel through the bark to the cambium where she begins to tunnel the simple longitudinal egg gallery (Fig. 2) up the tree in the inner bark, grooving the wood slightly. The male beetles crawl over the bark surface searching for mates and when a female is discovered excavating an entrance hole, he will stand by and follow her into the tunnel as she progresses.

Fertilization takes place when about an inch of egg gallery has been excavated in the inner bark. After fertilization, the female continues the egg gallery and the male either continues on with this female, assisting her in the disposal of the frass, or he leaves the gallery and wanders off in search of another mate.

The egg galleries range from three to twenty-three inches in length with an average of 9.1 inches. Eggs are deposited in alternate groups (Fig. 2) along the sides of the gallery; the egg groups containing from two to thirteen eggs. In the early attacked trees, i.e. those attacked in May and June, each female will deposit approximately thirty-two eggs which are distributed in the gallery as shown in Table I.

TABLE I

Average Distribution of Eggs
From Examination of 376 Galleries

Inches	1	2	3	4	5	6	7	8	9	10	11 to 20
No. of Eggs	1	4	6	5	4	3	2	2	2	2	0

The eggs are pearly-white in color, oval in shape, and average 1.19 mm. in length and .672 mm. in width. They hatch approximately fifteen days after being laid, so that larvae begin to appear early in June. The larvae construct feeding tunnels or mines at right angles to the egg gallery (Fig. 2), seventy days being required to pass through the five larval instars or stages. During this period of development, approximately forty per cent of the larvae pass from between the bark and wood into the inner bark where they are hidden from view when the bark is removed from the tree. When the larvae have reached the fifth and last instar, they excavate a shallow pupal cell in which they transform to pupae. The pupae begin to appear a few days before the middle of August and may be either exposed or hidden when the bark is removed, dependent on whether or not the larva had gone into the bark.

Seven or eight days are required for the pupal period and at the end of this time, the pupa sheds its skin and becomes a callow adult. These feed in the inner bark and overwinter in this stage to emerge and attack fresh hosts in May and June.

The parent beetles in the May and June attacked trees complete their galleries and emerge from the hosts during July. They then reattack

fresh green trees and raise a second brood. This brood develops at approximately the same rate as the first, overwinters in the larval stage and emerges during July and August to attack new trees.

A few points in the seasonal history of this insect are not known and more study is necessary to ascertain whether or not the second group of parent adults emerge from the old hosts and reattack green trees, and if so, when this occurs; also whether or not some of the early brood, which are callow adults in the fall of the year, emerge at that time and attack new trees.

Additional Biological Data

Parent Adult Emergence and Reattack

Emergence holes have been noted in trees which contained brood that was too immature for emergence, being only in the larval stage. Upon examination, it was found that these holes led from egg galleries, and this suggested the possibility of parent adult emergence, with subsequent attacks in a fresh host. It can readily be seen that if parent adult beetles do emerge from the tree after propagating one brood and attack another host to generate a second brood, the number of infested trees will be approximately twice the number normally to be expected.

To definitely connect one group of emerging parent adults with a subsequent attack, a wire screen cage (Fig. 3) was built around the basal ten feet of a green Douglas fir tree, and on June 12, 1931, Douglas fir logs and slabs from an infested tree, which had been attacked on May 16, 1931, were placed in the cage. The cage included a bark surface of 41.88 square feet on the green tree and the bark surface of the infested material placed

in the cage amounted to 47.41 square feet. By July 8, 1931, a very heavy attack had taken place within the cage on the green tree. Concurrent with the attacks within the enclosure, the tree was attacked above the cage thus showing that what had occurred within the cage was not abnormal and had not been induced by the caging. When the foliage began to fade and it was certain that the tree was dying, the cage was transferred to a green tree. The old tree was then felled and the formerly caged portion transferred to the cage on the green tree in order to ascertain if these parent adults will emerge and make a third attack. No further developments were noted when observations were last made on November 1, 1931. When the cage was removed from the first tree, the infested logs and slabs were examined so that a comparison might be had of the two broods raised by the same group of parent adults. However, the basal ten feet of the first tree is now in the cage on the new tree and examination of this material will not be made until next spring so that no comparison of broods can be given at this time.

From these data, it can be stated that parent adult Douglas fir beetles emerge from the May and June attacked trees and reattack living green trees. The study, however, is incomplete and two features are yet doubtful: namely, emergence and reattack by parent adults from the July attacked trees, and whether or not the beetles will generate a third brood. More caging experiments will be conducted during the coming field season to settle these points.

Proportion of Sexes

From time to time investigators have recorded an unequal proportion of male and female mountain pine beetles in the galleries of newly attacked

trees and these records brought up the question of the numerical inequality of sexes and its importance in the increase of the insect. Upon examination, it was found that this unequal proportion also existed in Douglas fir trees attacked by the Douglas fir beetle. It can readily be seen that if each brood contains more females than males, the infestation will increase beyond that normally expected in direct proportion to the number of extra females. Therefore, a study of the proportion of sexes was begun in connection with the other Douglas fir beetle investigations.

The first step in this study was to determine the ratio of male and female beetle to be found in newly attacked trees. Daily observations were made of a restricted area, and when attacks occurred in May, several trees were marked and the date of attack recorded. One or two of these trees were felled from time to time as the attacks progressed in age and examinations were made on all sides at varying heights along the bole. Each gallery was opened carefully from the entrance hole to the end of the gallery and the sexes of all beetles found were determined. Sex determinations were made according to the method described in a previous report* which consists simply of squeezing the beetle's abdomen so as to force the genetalia to protrude. Height and exposure on the tree show no effect on the sex proportion and have been omitted in recording the data in Table II.

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* Bedard, 1931 - New Facts Regarding the Biology of the Mountain Pine Beetle in Western White Pine. (Station Report)

TABLE II

PROPORTION OF SEXES IN ATTACKED TREES

Age of Attack in Days	No. of Galleries Containing: No Beetles	One Female	Male and Female	Total Males	Total Females	Per cent Males	Per cent Females	Sex Ratio
3	0	174	246	246	420	36.9	63.1	1:1.7 or 10:17
7	0	170	235	235	405	36.7	63.3	1:1.7 or 10:17
14	0	75	135	135	210	39.1	60.9	1:1.5 or 2:3
21	0	79	139	139	218	38.9	61.1	1:1.5 or 2:3
28	17	93	147	147	240	37.9	62.1	1:1.6 or 5:8
Total	17	591	902	902	1493	37.6	62.4	1:1.6 or 5:8

From Table II it can be seen that the variation in the proportion of sexes due to the age of attack is so very slight that it can be considered as eight females to every five males for the season of 1931. This is practically the same ratio as was obtained from a similar study* of the mountain pine beetle in white pine, which showed three females to every two males.

To determine whether or not this ratio would be applicable to the beetles as they emerge from the old brood trees, prior to the attack on the fresh hosts, Douglas fir bark, from which D. pseudotsugae brood was about to emerge, was placed in a large galvanized can. This can was especially constructed with a bottom sloping towards a hole in the center so that all emerging insects would fall below into a glass container. The container was emptied each day and the sex of each mountain pine beetle determined by dissection under the microscope. When emergence was complete, it was found that of the 247 beetles 49.3 per cent were males, and 50.7 per cent females, thus making a proportion of one male to one female.

To substantiate this finding, 768 callow adult beetles were collected at random, at different times, from different trees, and were dissected under the microscope to determine the sex. Including the can emergence, 1015 beetles were so examined, and of these 501 (49.3 per cent) were males and 514 (50.7 per cent) were females.** Thus there is an equal number of males and females when the new adults emerge from the trees and

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* Bedard, 1931 - New Facts Regarding the Biology of the Mountain Pine Beetle in Western White Pine. (Station Report)

** A similar study of 1,000 mountain pine beetles showed 497 (49.7 per cent) males, and 503 (50.3 per cent) females for the emerging brood.

therefore an unequal sex proportion does not enter as a factor which causes an increase of D. pseudotsugae beyond that normally expected.

Exactly what happens to the males between the time of emergence and attack, so as to cause the numerical inequality of sexes found in newly attacked trees, is difficult to say. I am inclined to state that they are eaten by predators. Clerids especially were very abundant in the region and as the male beetles, following the females into the galleries, are exposed for a much longer time, it seems logical that more males than females would fall prey to the predators. Another possibility is that after fertilizing one female, the male may wander off in search of a new mate and in the course of his wanderings, besides exposing himself for an additional time to predators, may die due to a number of agencies other than predators.

Concerning the proportion of sexes, additional study will be made of the trees attacked in July and August and an attempt will be made to ascertain the exact fate of the males.

Parthenogenesis and Mating Habits

This excess of females in the newly attacked trees naturally created the question as to how they became fertilized, because Dendroctonus pseudotsugae has always been considered a monogamic species. Only three theories were advanced to answer this question: first, fertilization took place before the beetles left the old tree; second, the females had parthenogenetic ability which they could use at will; and third, some males fertilized more than one female. The theory of parthenogenesis will be considered first.

Thirteen large Douglas fir beetle pupae were placed in separate rearing jars and kept as near natural conditions as possible until the resulting adult beetles were fully mature. Thus being certain that these beetles were unfertilized, a fresh block of Douglas fir was inserted in each of the thirteen jars and allowed to remain there for four weeks. Upon examination it was found that only six beetles had attacked the blocks. All six had constructed short irregular galleries of from one to three inches, but had laid no eggs. The six beetles were examined and found to be females. A check of this experiment existed in the form of successfully developing brood in similar blocks. This brood had been obtained by introducing male and female beetles into jars and rearing the brood from the eggs, thus showing that had the unfertilized females laid fertile eggs, the rearing device would not have hindered the development of these eggs.

In addition, twenty-six mature D. pseudotsugae adults were taken from individual pupal cells and each one was placed separately on a newly attacked Douglas fir tree with a small piece of screen tacked over it to keep it isolated from all other beetles. Examination was made at the end of four weeks and it was found that nine beetles had made no attack, fourteen had constructed short irregular galleries but laid no eggs, and three had constructed short irregular galleries and deposited a few eggs which did not hatch. All attacking beetles were examined and found to be females. In this experiment, successfully developing brood was present in the same tree all around the screened galleries.

Table III shows the results of these experiments.

TABLE III

PARTHENOGENESIS EXPERIMENTS

Group	Type Experiment	No. of Beetles	Attack	Inches of Gallery	No. of Eggs
I	Rearing jars and fir blocks	7	No		
		2	Yes	1	0
		1	Yes	2	0
		3	Yes	3	0
II	Screened on tree.	9	No		
		5	Yes	1	0
		7	Yes	2	0
		2	Yes	3	0
		1	Yes	3	1
		1	Yes	3	3
		1	Yes	3	4

These data show the absence of parthenogenesis in the case of D. pseudotsugae.

To determine whether mating takes place before the beetles leave the old tree or is perpetrated after arrival on the new host, eight new adult Douglas fir beetles were collected crawling on the bark of a Douglas fir tree which was just being attacked. These beetles were placed in separate rearing jars and a fresh block of Douglas fir was placed in each jar. Five beetles attacked almost immediately, but the remaining three crawled about and at the end of a week had died. The three were examined and found to be males. Final examination of the blocks was made at the end of five weeks and it was discovered that all five beetles had constructed short irregular galleries of from one to four inches, and, upon dissection, all five beetles were found to be females. Two galleries contained three and seven eggs respectively, but these eggs did not hatch. The other three galleries

contained no eggs.

In addition, a piece of Douglas fir bark containing eleven Douglas fir beetle new adults about ready to emerge, was placed in a cage. This was allowed to stand for two days and on the morning of the third day a fresh slab of Douglas fir was placed in the cage. Seven beetles began attacks a few hours after the slab had been placed in the cage. The remaining four beetles wandered over the bark for a considerable period, but at the end of five hours each one of the four had selected one of the new attacks and was following the attacking beetle. On the next day two of these pairs were transferred to a glass plate rearing device (Fig. 4) which consisted simply of a thin sheet of inner bark held between two plates of ordinary window glass. The bark was pared to such thinness as to allow the beetles just sufficient room to work between the glass plates, yet kept them visible to the eye at all times. Cotton was packed around the bark between the two plates and moistened daily so as to prevent excess drying of the bark. On the second day after the transfer, copulation was observed taking place in one of the galleries. Fertile eggs were laid in both galleries and normal brood developed. Upon examination, one male and one female was found in each gallery.

Of the seven beetles which remained in the cage, there were three attacks made by single beetles, and two attacks each containing a pair of beetles. In one of these pairs the beetle which was following the other was removed and dissected under the microscope. Examination proved it to be a male and the gallery from which he had been taken was marked. Of the single beetles, two were transferred to a glass plate rearing device.

At the end of five weeks, final examination showed that all single beetles were females and had laid no eggs. Their galleries were short and gouged out which seemed to be characteristic of the galleries made by the unfertilized females in the parthenogenesis experiments. The other gallery containing a male and female produced a normal brood.

In a somewhat similar experiment conducted with the mountain pine beetle, ten females and four males produced ten attacks, five of which had normal broods.

These data indicate that mating takes place after the beetles reach the newly attacked tree and in the newly constructed gallery. Some males become polygamous in that after having fertilized one female, they emerge and seek another mate, while others remain monogamous. Just what causes some males to wander off and become polygamic is not known.

To substantiate these conclusions, three galleries were observed in newly attacked trees in each of which a pair of beetles were in the act of copulation.

Brood Potential

In the administration of a control project, or in the survey of an area to determine the advisability of control, it is of great importance to be able to predict the potential danger of a unit of infested material. For this reason, a study of brood potential was conducted by means of brood counts in connection with the Douglas fir beetle investigations.

Samples of Douglas fir bark were examined and the number of individuals per square foot of bark surface recorded. These examinations were made at various times in order to secure counts of the divers brood

stages. For example, bark examinations were made early in the season to ascertain the number of eggs per square foot; later, counts were made when only larvae were present in the trees, and so on. In this way, the decrease in brood from one stage to the next, i.e. from egg to larva, larva to pupa, etc., is secured and thus the mortality for each stage can be calculated. The results of these examinations are shown in the following table:

TABLE IV

BROOD POTENTIAL AND MORTALITY

Stage	Sq. ft. of bark examined	Individuals per sq. ft.	Decrease to next stage	Per cent Mortality	Per cent of Total Mortality
Egg	203	168	105	62.5	62.5
Larval	141	63	31	49.2	18.5
Pupal	94	32	7	21.8	4.1
Callow Adult	149	25	7	28.0	4.1
Emergence Holes	164	18		Total Mortality	89.2

As there is an average of seven attacks per square foot of bark surface and two beetles to the attack, it can readily be calculated that the beetles emerging from one square foot of bark will be sufficient to infest a bit over one square foot in the new host; or to eliminate fractions, adults emerging from seven square feet will be sufficient to infest nine square feet. Then, parent adult emergence and reattack will approximately double the new infestation, so that considering our unit as trees in place

of square feet, seven infested trees will produce eighteen infested ones the following year. This makes a ratio of increase between 1:2.5 and 1:2.6. However, this increase will be tempered by an immeasurable factor which can only be estimated at this time. This factor is the beetle mortality which occurs between emergence of the new adults and attack in the new host, and between emergence and reattack by parent adults. Using as a basis the increased number of trees over last year's infestation, I would judge the final ratio of increase, after deducting the flight mortality factor, to be between 1:1.5 and 1:2.0.

However, it must be remembered that this ratio of increase will vary with the infestation and that the above figures are only directly applicable to the infestation in the vicinity of Metaline Falls, Wn., on the Kaniksu National Forest. Infestations which are decreasing will show a ratio of increase which is less than one to one and increasing infestations will show a higher figure, depending on the rapidity of the increase. Nevertheless, this figure will serve as a basis whereby other infestations can be judged.

SAMPLE PLOTS

One tenth acre sample plot has been established on each of the four cardinal exposures and one on a creek bottom, making a total of five plots. These will be used to trace the ecological phenomena which occur in a stand of Douglas fir that has been infested by the Douglas fir beetle. It is also hoped that some of the factors influencing the beetle's preference for particular trees within the stand will be obtained from these plots.

Increment cores have been taken from four sides of each Douglas

fir within the plots as well as from infested and uninfested trees adjacent to the plots. These cores have been analysed and the data indicate a correlation between tree growth and attack. However, the material is not sufficient to use as a basis for making a positive statement at this time.

CONTROL

In conjunction with the biological studies, two methods of artificial control were tested. One method consisted of felling and peeling the infested trees and the other of injecting infested trees with liquids which are toxic to the insects. No examinations have been made of the trees thus controlled and consequently results cannot be given at the present time. However, the methods and procedure will be described in this report.

In addition to the artificial control experiments, a study was made of some of the agents active in the biological control of the Douglas fir beetle and an attempt was made to evaluate each of these. However, a discussion of only the more important ones will appear in this report.

Artificial Control

For the peeling experiments, six infested Douglas fir trees were felled and peeled. Previous to peeling, brood counts were made on all trees so as to obtain a figure whereby the per cent of control could be calculated. During the 1932 field season, some of the bark from these trees will be placed in the galvanized cans used in the sex studies to determine the per cent of brood which emerges. In addition, caging experiments with green logs will be conducted around the controlled trees,

and in this way it is hoped to ascertain whether or not the beetles will successfully overwinter in the bark or duff and emerge in the spring to attack a fresh host.

Five infested trees were used in the tree medication experiments and each one was injected with a different solution of poison as follows: one tree with one-half pound of sodium arsenate to three quarts of water, one tree with one-half pound of sodium arsenate to two quarts of water and one quart of wood alcohol, one tree with one quarter pound of sodium arsenate to two quarts of water and one quart of wood alcohol, one tree with one-half pound of sodium arsenate to four and one-half pints of water and one and one-half pints of wood alcohol, one tree with three quarts of wood alcohol. The solutions were injected into the trees by cutting a saw kerf around the base of the tree to a depth of one quarter of an inch and nailing a tin collar (Fig. 5) around the tree just below the kerf. The liquid was then poured into the collar to be absorbed and distributed by the conducting tissues of the tree. Leaking of the collar was prevented by smearing a mixture of paraffin, lubricating grease, and linoleum cement on the tree at the point where the collar was fastened. Examination of these trees will be made in the spring of 1932.

Biological Control

In Table IV it has been seen that there is a natural mortality of approximately eighty-nine per cent in each Douglas fir beetle brood. However, as much of the data is incomplete at the present time, it will be impossible to correctly apportion this percentage in order to give the proper value to each of the responsible biological agencies. Several

points in the seasonal histories and habits of the parasites and predators are also lacking so that only an annotated list will be given in this report of those enemies of the Douglas fir beetle which have been definitely established.

Mites (Arachnida - Acarida)

Two undetermined species of mites have been observed in the newly constructed beetle galleries feeding on D. pseudotsugae eggs. These arthropods have also been kept in the laboratory and fed on barkbeetle eggs. They are very numerous in the galleries and I believe account for a large percentage of egg mortality.

Coeloides brunneri Vier. (Hymenoptera - Bracondidae)

This insect was found to be the most important larval parasite of the Douglas fir beetle, parasitizing an average of twenty-nine per cent of the larvae. However, this percentage varies with the height of the tree, and a greater number of Coeloides cocoons will be found at the top of the tree than at the base. In the trees observed, between seventy and ninety-five per cent of the beetle larvae had been parasitized in the upper ten feet of the infested tree length as compared with from zero to ten per cent at the base. The cause of this variation has not as yet been determined.

Cecidostiba dendroctoni Asm. (Hymenoptera - Pteromalidae)

This species was quite numerous in infested Douglas fir trees and parasitizes the larvae of the Douglas fir beetle. An undetermined Pteromalid, which also was fairly abundant on the newly attacked trees, I believe to be another species in this genus.

Pachyceras eccoptogasteri Ratz. (Hymenoptera - Pteromalidae)

Similar to the above insect, this larval parasite was fairly

abundant on the newly infested trees, and probably has approximately an equal economic value as a control agent.

Medeterus sp. (Diptera - Dolichopodidae)

The larvae of Medeterus (probably aldrichi Wh.) are one of the two most important predators which prey upon the immature stages of the Douglas fir beetle. They are voracious feeders and consume not only the eggs, larvae and pupae of the Douglas fir beetle, but have been observed feeding on Coeloides larvae as well as on each other.

Lonchaea sp. (Diptera - Lonchaeidae)

This is probably Lonchaea viridana Meigen, and the larvae prey upon the immature stages of D. pseudotsugae. It is the other of the two most important predators associated with the Douglas fir beetle. Like Medeterus, they do not confine their feeding strictly to the beetle broods, but will attack other species as well. Both Lonchaea and Medeterus are abundant in newly attacked trees.

Nudobius sp. (Coleoptera - Staphylinidae)

Both the larvae and the adults of this insect dwell beneath the bark of infested Douglas fir trees and feed upon the immature stages of the Douglas fir beetle.

Quedius sp. (Coleoptera - Staphylinidae)

This insect is similar to Nudobins in that both the imagines and the larvae prey upon the eggs, larvae and pupae of the Douglas fir beetle. Both Quedius and Nudobius are quite vicious in habits and those reared in the laboratory would quarrel and struggle for food in the event that only one D. pseudotsugae larva was placed in a vial containing two

or more of these predators.

Thanasimus dubius Lec. (Coleoptera - Cleridae)

Enoclerus sphegeus Fab. (Coleoptera - Cleridae)

Enoclerus lecontei Wolc. (Coleoptera - Cleridae)

These three Clerids are found on infested Douglas fir trees while attack by the Douglas fir beetle is taking place. The imagines feed on the adult beetles and the larvae feed on the immature stages. E. sphegeus is by far the most abundant of the three with T. dubius slightly less abundant. E. lecontei borders on rareness in the Douglas fir although it is fairly common in the region.

Cucujus clavipes Fab. var. punicens Mann. (Coleoptera - Cucujidae)

Temnochila virescens Fab. var. chlorodea Mann. (Coleoptera - Ostomidae)

The larvae of these two insects feed on the larvae of the Douglas fir beetle. Cucujus is quite abundant but Temnochila is not very common in the Douglas fir.

SUMMARY

The chief findings of the investigation are as follows:

1. First attacks by the Douglas fir beetle occur between the middle of May and the early part of June. The brood generated by this attack overwinters in the callow adult stage and emerges as new adults in May and June of the following year.

Parent adults emerge from the trees in July, after depositing eggs for the first brood, and reattack fresh hosts to propogate a second brood which overwinters as larvae and emerges as new adults in July of

the following year.

2. The proportion of males and females as the new adults emerge from the old trees is one male to one female. However, due to a heavier mortality among the males, this proportion is changed to eight females to five males in newly attacked trees.

3. Dendroctonus pseudotsugae Hopk. does not reproduce parthenogenetically.

4. The ratio of increase for the Douglas fir beetle was found to be between 1.5 and 2.0 in the infestation in the Sullivan Creek drainage, Kaniksu National Forest.

5. The following enemies of the Douglas fir beetle were found associated with it:

Arachnida

Mites (Acarida)

Hymenoptera

Coeloides brunneri Vier. (Braconidae)

Cecidostiba dendroctoni Asm. (Pteromalidae)

Pachyceras eccoptogasteri Ratz. (Pteromalidae)

Diptera

Medeterus sp. (Dolichopodidae)

Lonchaea sp. (Lonchaeidae)

Coleoptera

Nudobius sp. (Staphylinidae)

Quedius sp. (Staphylinidae)

Thanasimus dubius Lec. (Cleridae)

Enoclerus sphegeus Fab. (Cleridae)

Enoclerus lecontei Wolc. (Cleridae)

Cucujus clavipes Fab. var. puniceus Mann. (Cucujidae)

Temnochila virescens Fab. var. chlorodia Mann. (Ostomidae)

Fig. 1 - South slope of Sullivan Mt. showing Douglas fir trees killed by D. pseudotsugae. Dead trees appear white. (Photo by H. J. Rust)

Fig. 2 - Galleries of D. pseudotsugae in Douglas fir bark. This shows how the female beetles deposit eggs in groups along the sides of the egg gallery.

(Photo by H. J. Rust)

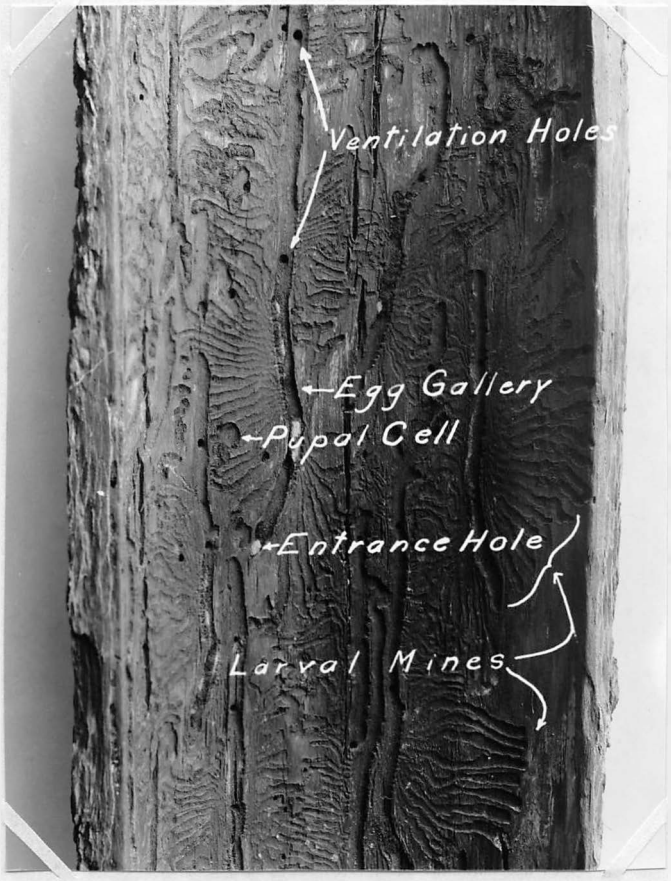
Ventilation Holes
Egg Gallery
Pupal Cell
Entrance Hole
Larval Mines

Fig. 3 - Type of cage used for the parent adult emergence studies. The bottom edges of the screen are buried in the ground.

Fig. 4 - Glass plate rearing device. Parent adult beetles can be seen at the ends of the galleries, and eggs are visible along the sides of the galleries.

(Photo by H. J. Rust)

Fig. 5 - Tin collars on Douglas fir trees. Some of the trees used in the injection experiments.

Fig. 6 - Hibernacula of *Coeloides brunneri* Vier. at the ends of *D. pseudotsugae* larval mines.

(Photo by H. J. Rust)